

In practice, before the exposure is commenced, the apparatus is arranged so that the screw H gives a motion in R.A. to the plate, and V a motion in declination; then any star on the edge of the field is fixed upon and the cross-wires brought directly over it. Throughout the exposure this star is kept under view; the eyepiece being very powerful, the smallest errors become apparent to the eye, and can be corrected at once by the screws. If from any cause it is necessary to discontinue the exposure the plate can be shut up, and the exposure can be recontinued at any time if the guiding star is brought exactly to the cross-wires, for then the plate is in the same position as it was before the interruption. The wires being in exactly the same plane as the film, any alteration of focus can be at once detected in the eyepiece and corrected at once by the focussing-wheel.

Spectroscopic Observations of sundry Stars and Comets, made at the Royal Observatory, Greenwich, chiefly in the years 1887 and 1888. By E. W. Maunder.

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I. γ CASSIOPEÆ and β LYRÆ.

The object of the following observations was to detect any bright lines in the spectra of these two stars, to watch if such lines varied in brightness, and to determine the wave-length of the bright line near the D lines, supposed to be D_3 .

The instruments employed were the half-prism spectroscope, with one half-prism, either in the direct or reversed position, and the single-prism spectroscope, with one large prism of 60° . The dispersions of the three instruments are as follows:—

	A to H.	Power of Eyepiece.
Half-prism spectroscope, Direct	$18\frac{1}{2}$	14
„ „ Reversed	5	30
Single-prism spectroscope	$4\frac{2}{3}$	10

These were mounted on the South-East equatorial, of 12·8 inches' aperture, and were used either with or without a cylindrical lens before the slit.

γ Cassiopeiae.

Single-prism spectroscope.

Three bright lines were observed, viz. C, F, and a line near D, supposed to be D_3 . These three lines, if seen at all, were seen as bright lines, never as dark.

Date.	Cylindrical Lens before slit.		
	C	D ₃	F
1887, Feb. 16	Not seen	Not seen	Very distinct
Dec. 5	<i>Brilliant</i>	Not seen	Faint
16	Not seen	Not seen	Faint
1888, Sept. 19	Very bright	Faint	Rather faint

	No Cylindrical Lens.		
	C	D ₃	F
1887, Feb. 16	Not seen	Not seen	Very distinct
Dec. 5	<i>Brilliant</i>	Not seen	Faint
16	Distinctly seen	Not seen	Not seen
1888, Sept. 19	Very bright	Faint	Rather faint

Half-prism spectroscope, direct. Cylindrical lens before slit.

The C and D₃ lines were not looked for. The F line was observed as follows:—

Date.	Description of Bright F line.
1880, Oct. 1	Brilliant against the background of the continuous spectrum. Broad and diffused at edges. Central condensation.
Nov. 21	Bright.
1881, Dec. 7	Difficult to measure.
1883, Nov. 16	Easily seen.
1884, Aug. 11	Faint.
25	Faint.
Sept. 4	Very faint.
10	Barely visible.
11	Measured. No remarks made.
18	Very faint.
20	Faint. Sharp; well-defined at edges.
1887, Feb. 16	Very faint. Narrow.
Oct. 19	Distinctly a bright line. Broad, and diffused at edges.
1888, Dec. 13	Faint. Narrow, and slightly diffused at edges.

Half-prism spectroscope, reversed. Both with and without a cylindrical lens before the slit.

1887, Dec. 16. Observations made with single-prism spectroscope confirmed.

β Lyræ.

The same three lines—viz. C, D₃, and F—were observed as in the spectrum of *γ Cassiopeie*. D₃ was always seen as a bright line if seen at all, but C and F were on one occasion—1888, October 19—suspected to be represented by dark lines.

Half-prism spectroscope, reversed.

Date. 1887.	Cylindrical Lens before slit.			No Cylindrical Lens.		
	C	D ₃	F	C	D ₃	F
Dec. 16	Not seen	Not seen	Not seen	? Bright	Not seen	Not seen

Single-prism spectroscope.

1888.						
Aug. 10	Not seen	Not seen	Not seen	Not seen	Fairly bright	Very faint
Sept. 10	...	...	...	Not seen	Faint	Not seen
19	...	...	...	Not seen	Bright	Not seen
21	Not seen	Very bright	Bright	Bright	Very bright	Bright
Oct. 19	...	...	...	? Dark line	Very faint	? Dark line

The appearance of the three lines as seen on 1888, September 21, was as follows:—

C—Narrow and sharp.

D₃—Very bright, narrow, sharp, and well defined.

F—Rather brighter than C, not nearly so bright as D₃, and somewhat ill-defined at the edges.

The D₃ line, on each occasion when it was seen, appeared to be narrow, sharp, and well-defined.

The following results were obtained for the wave-length of the bright line supposed to be D₃, by measurement of its distance from the D lines as given by a sodium flame:—

Wave-length inferred for the bright line near D.

1888, Aug. 10 ; tenths-metres.		1888, Sept. 19 ; tenths-metres.	
	5874·46		5875·76
	5·70		5·82
	3·10		4·58
	1·55		0·80
	3·59		2·79
	6·07		4·65
	5·64		6·88
	2·17		3·16
	3·34		6·13
	3·59		5·33
Mean	5873·92	Mean	5874·59
Mean of all the measures		5874·26	

General Remarks on the Spectra of γ Cassiopeiae and β Lyræ.

The foregoing observations appear to show that—

- (1) The spectra of both stars show bright lines.
- (2) These bright lines are variable in brightness.

(3) In the case of γ *Cassiopeia*, the three bright lines observed do not vary simultaneously and in the same manner.

(4) In the case of β *Lyræ*, the observations are not sufficient to establish any conclusion, but are not inconsistent with a simultaneous variation of all the three lines observed.

(5) Two of the three lines observed are the C and F lines—the first and second lines, that is, of hydrogen. The measures made of the position of the bright line near D in the spectrum of β *Lyræ* point to its being the so-called “helium” line D_3 , and not the fluting of manganese at λ 5869. Its appearance—that of a narrow, sharp, well-defined line—also agrees with this view.

(6) The observations in the case of β *Lyræ* are not sufficient to prove that the variations in the brightness of the D_3 line take place in a similar period to that of the variations in the brightness of the star itself, but they are not inconsistent with such a relation. Arranging the observations in order of the observed brightness of the D_3 line, the following table shows the interval from the next preceding chief minimum :—

Character of D_3 .	Date of Observation.		Interval after the last Chief Minimum.	
		h	d	h
Very bright	1888, Sept. 21	20	7	11
Bright	19	21	5	11
Fairly bright	Aug. 10	22	4	6
Faint	Sept. 10	21	9	9
Very faint	Oct. 19	20	9	14
Not seen	1887, Dec. 16	21	11	17

As the secondary minimum falls $6^d 11^h$ after the chief minimum, and the maximum following the secondary minimum about $9^d 16\frac{1}{2}^h$ after the chief minimum, the observations are not inconsistent with a maximum brightness of the D_3 line soon after the secondary minimum of the star, followed by a decline to a minimum soon after the second maximum of the star.

(7) The D_3 line is the most conspicuous bright line in the spectrum of β *Lyræ*, but either C or F is the most conspicuous in that of γ *Cassiopeia*.

II. STARS WITH SPECTRA OF THE THIRD TYPE (SECCHI'S).

o Ceti (Mira) near Maximum.

1888, October 5.—The spectrum of the star had a remarkably clean appearance, the “zones,” or bright interspaces between the dark shaded bands, being quite free from absorption lines. Bands I., V., VII., and VIII. (Dunér's numeration) were very distinct, and all were sharp towards the violet, and shaded towards the red. Band IV. was faint, but appeared to be of the

same character as those just mentioned. Band III. was, as usual, a little shaded at *both* edges and darkest in the middle, but more nearly of a uniform shade than any of the other bands. Band IX. was found to be a rather puzzling object. Being far in the blue, it was a little difficult to make out, but it seemed at times to have its edge about 33 tenth-metres nearer to the red than at others, or at λ 4797 instead of λ 4764. Probably it consisted of two bands close together. Band IX. was faint. Bands VII. and VIII. were the darkest in the spectrum. Beyond Band VIII., towards the violet, the bands were most difficult to see, as they were so faint; but the continuous spectrum itself could be traced an unusually great distance into the violet. The violet end was very free from selective or general absorption. Bright lines at or near F and D₃ were carefully looked for, but none were seen. But a bright line in the violet, evidently the third line of hydrogen, was very distinctly seen, and several measures were obtained of its position, as follow:—

Tenth-metres.		Tenth-metres.
4346		4345
4344		4342
4343		4343
4343		4345
4342	Mean	4343'4
4341		

1888, *December* 1.—The dark bands in the spectrum of *Mira* were of intense blackness, as if slices had been cut clean out of the spectrum; Bands VII., VIII., and IX. being especially broad and black; Band VIII. the broadest and blackest of all. They seemed as if a little further expansion would make them swallow up the whole of this portion of the spectrum. The bands were less intensely marked as the red end of the spectrum was approached; the red and yellow portions of the spectrum were faint, and perhaps the bands in those districts were less easily seen on that account. The D lines could not be identified, nor could some faint bands close to D on the more refrangible side, which had been noticed the same evening in the spectrum of β *Pegasi*, be detected in this spectrum. On the other hand, a faint band, not seen in β *Pegasi*, was observed in *Mira*, below D towards the red.

Positions of the Dark Bands in Stellar Spectra of the Third Type (Secchi's).

No. of Band, Dunér's Numeration.	1876, Jan. 28.	α Orionis, 1876, Feb. 29.	1887, Dec. 16.	β Pegasi, 1876, Oct. 18.	1876, Oct. 18.	ρ Persel. 1876, Oct. 18.	1877, May 7.	α Herculis, 1877, June 4.	1877, July 2.	1888, May 2.	Mira, α Ceti, 1888, Oct. 5.	Mean.
Band I.	...	6482 \pm	6540 \pm	...	...	...	6560 \pm	...	6600 \pm	...	6587 \pm	6554 \pm
Band II.	6198	6146	6173	6169	6168	6153	6161	...	6152	6153	6153	6163
A faint band	...	6050	...	...	...	...	...	...	...	...	...	6050
Band III.	5863	5850	5859	5869	5870	5866	...	...	5861	5865	5842	5861
A second edge to Band III.	...	...	5822	5830	...	...	5825	...	5824	...	...	5825
A faint band	5741	...	5779	5750	...	...	...	...	...	...	...	5757
Band IV.	...	5563	5577	5610	5610	5608	5608	...	5620	5592	5606	5599
Band V.	5459	5446	5445	5450	5446	5445	5445	5448	5456	5452	5448	5449
Band VI.	5251	5251	...	5272	...	...	...	...	...	...	...	5258
Band VII.	5165	5165	5164	5164	5167	5160	5169	5169	5169	5167	5171	5166
Band VIII.	4951	4951	4954	4953	4956	4950	4963	...	4956	4960	4956	4955
Band IX.	4758	4761	4780	4761	...	4752	4759	...	4771	4776	4764	4765
Band X.	...	...	4603	4595	...	4641 \pm	...	...	4567	4609	...	4602
Band XI.	4446 \pm	...	...	4360 \pm	...	4359 \pm	...	...	...	...	...	4388 \pm

The above determinations of the wave-lengths of the less refrangible edges of the dark bands in stellar spectra of the third type (Secchi's) were made with micrometer B of the single-prism spectroscope, measures of the position of the D lines, as given by a sodium flame, being made on each occasion for index error. The measures of the stellar bands, after correction for index error, have been converted into wave-lengths by reference to a curve connecting micrometer readings and wave-lengths, and laid down from a series of measures of the principal lines in the solar spectrum made with the same instrument.

III. P AND R CYGNI.

The object of these observations was the detection and measurement of bright lines in the spectra of the two stars.

R Cygni.

R Cygni was observed on 1888, September 21 and October 1. On the former occasion bright lines were observed near D₃ and F, but, a mist rising, the star was lost before any measures could be obtained. On October 1 only the F line was seen as bright, and its position was measured once, the resulting wave-length being

Tenth-metres

4866.

The general spectrum of the star, apart from the bright line at F, appeared to be that of Secchi's fourth type—viz. one crossed by shaded dark bands, which are sharp and dark on their less-refrangible side and shade off towards the violet.

P Cygni.

P Cygni was observed on 1888, October 1, and the following measures were obtained for the position of a bright line in its spectrum :—

Tenth-metres.		Tenth-metres.
4861		4860
4859		4858
4859		4852
4862		4853
4860	Mean	4858.4
4860		

The bright line, which appeared a little diffused at the edges, was observed without much difficulty. No other bright lines were detected, and, no cylindrical lens being used, no dark bands could be made out.

The single-prism spectroscope was used both for *R* and *P Cygni*, and no cylindrical lens was employed. The D lines, as given by a sodium flame, were used as a reference spectrum for index error, as in the measures given in Section II.

IV. COMETS 1888 *a* AND 1888 *e*.

These two comets were observed with the single-prism spectroscope, without a cylindrical lens.

Comet 1888 a (Sawerthal)

was observed on 1888, April 10, 19, and May 3. The spectrum was almost wholly continuous, but on April 19 two very feeble bright bands were detected, nearly, if not quite, coincident with the bands in the green and yellow of the spectrum of the Bunsen flame. In the case of the band in the green a direct comparison was made between the two spectra, which left no doubt of their coincidence. The third carbon band—that in the blue—was not quite satisfactorily made out, but its presence was suspected as a slight local brightening of the continuous spectrum. On May 3 no trace of the yellow and blue bands could be detected in the spectrum of the comet, and the presence of the green band was only very faintly suspected. The spectrum of the comet was practically wholly continuous. It ended rather abruptly at or near D.

The spectrum of the tail was followed to a considerable distance from the nucleus, but it differed from that of the nucleus only in its greater faintness.

Comet 1888 e (Barnard 1888, September 2)

was observed on 1888, November 27. The spectrum was almost wholly continuous. By carefully narrowing the slit it became possible to see that there was a local, ill-defined brightening, corresponding nearly to the green carbon band, but apparently further towards the blue. On narrowing the slit further this brightening was lost, and only the continuous spectrum was seen. This was noted only for the nucleus and its immediate neighbourhood, the fainter outlying portions of the coma not being bright enough to give a perceptible spectrum with the slit as now narrowed. On the whole, the evidence for anything beyond a purely continuous spectrum was but small; the hydrocarbon spectrum was evidently quite an unimportant and subordinate feature.

A A